COMESA 224 (2006) (English): Overhead electrical conductors - Formed wire, concentric lay, stranded conductors

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COMESA HARMONISED STANDARD

COMESA/DHS 224: 2005

Overhead electrical conductors - Formed wire, concentric lay, stranded conductors

REFERENCE: DHS 224: 2005

Foreword

The Common Market for Eastern and Southern Africa (COMESA) was established in 1994 as a regional economic grouping consisting of 20 member states after signing the co-operation Treaty. In Chapter 15 of the COMESA Treaty, Member States agreed to co-operate on matters of standardisation and Quality assurance with the aim of facilitating the faster movement of goods and services within the region so as to enhance expansion of intra-COMESA trade and industrial expansion.

Co-operation in standardisation is expected to result into having uniformly harmonised standards. Harmonisation of standards within the region is expected to reduce Technical Barriers to Trade that are normally encountered when goods and services are exchanged between COMESA Member States due to differences in technical requirements. Harmonized COMESA Standards are also expected to result into benefits such as greater industrial productivity and competitiveness, increased agricultural production and food security, a more rational exploitation of natural resources among others.

COMESA Standards are developed by the COMESA experts on standards representing the National Standards Bodies and other stakeholders within the region in accordance with international procedures and practices. Standards are approved by circulating Final Draft Harmonized Standards (FDHS) to all member states for a one Month vote. The assumption is that all contentious issues would have been resolved during the previous stages or that an international or regional standard being adopted has been subjected through a development process consistent with accepted international practice.

COMESA Standards are subject to review, to keep pace with technological advances. Users of the COMESA Harmonized Standards are therefore expected to ensure that they always have the latest version of the standards they are implementing.

This COMESA standard is technically identical to the International Standard *IEC 62219:2002.*

NORME INTERNATIONALE

INTERNATIONAL STANDARD

CEI
IEC
62219

Première édition
First edition
2002-02

Conducteurs pour lignes électriques aériennes – Conducteurs à fils de forme, câblés en couches concentriques

Overhead electrical conductors – Formed wire, concentric lay, stranded conductors

Numéro de référence
Reference number
CEI/IEC 62219:2002

Numérotation des publications

Depuis le 1er janvier 1997, les publications de la CEI sont numérotées à partir de 60000. Ainsi, la CEI 34-1 devient la CEI 60034-1.

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Les versions consolidées de certaines publications de la CEI incorporant les amendements sont disponibles. Par exemple, les numéros d'édition 1.0, 1.1 et 1.2 indiquent respectivement la publication de base, la publication de base incorporant l'amendement 1, et la publication de base incorporant les amendements 1 et 2.

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- **IEC Web Site (www.iec.ch)**
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Conducteurs pour lignes électriques aériennes – Conducteurs à fils de forme, câblés en couches concentriques

Overhead electrical conductors – Formed wire, concentric lay, stranded conductors

International Electrotechnical Commission, 3, rue de Varembé, PO Box 131, CH-1211 Geneva 20, Switzerland
Telephone: +41 22 919 02 11 Telefax: +41 22 919 03 00 E-mail: inmail@iec.ch Web: www.iec.ch

Commission Electrotechnique Internationale
International Electrotechnical Commission
Международная Электротехническая Комиссия

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

OVERHEAD ELECTRICAL CONDUCTORS – FORMED WIRE, CONCENTRIC LAY, STRANDED CONDUCTORS

FOREWORD

1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, the IEC publishes International Standards. Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. The IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of the IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested National Committees.
3) The documents produced have the form of recommendations for international use and are published in the form of standards, technical specifications, technical reports or guides and they are accepted by the National Committees in that sense.
4) In order to promote international unification, IEC National Committees undertake to apply IEC International Standards transparently to the maximum extent possible in their national and regional standards. Any divergence between the IEC Standard and the corresponding national or regional standard shall be clearly indicated in the latter.
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6) Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. The IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 62219 has been prepared by IEC technical committee 7: Overhead electrical conductors.

The text of this standard is based on the following documents:

FDIS	Report on voting
7/539/FDIS	7/540/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 3.

Annexes A, B and C form an integral part of this standard.

Annex D is for information only.

The committee has decided that the contents of this publication will remain unchanged until 2007. At this date, the publication will be

- reconfirmed;
- withdrawn;
- replaced by a revised edition, or
- amended.

OVERHEAD ELECTRICAL CONDUCTORS – FORMED WIRE, CONCENTRIC LAY, STRANDED CONDUCTORS

1 Scope

This International Standard specifies the electrical and mechanical characteristics of concentric lay, overhead conductors of wires formed or shaped before, during or after stranding, made of combinations of any of the following metal wires:

a) hard aluminium as per IEC 60889 designated A1;
b) hard aluminium as per IEC 60889 designated A1F wire shaped before stranding;
c) hard aluminium alloy as per IEC 60104 designated A2 or A3;
d) hard aluminium alloy as per IEC 60104 designated A2F or A3F shaped before stranding;
e) regular strength steel, designated S1A or S1B, where A and B are zinc coating classes, corresponding respectively to classes 1 and 2;
f) high strength steel, designated S2A or S2B;
g) extra high strength steel, designated S3A;
h) aluminium clad steel, designated SA.

The following are examples of some possible conductor designations. Other combinations are also permitted.

- A1F, A2F, A3F
- A1F/S1A, A1F/S1B, A1F/S2A, A1F/S2B, A1F/S3A
- A1F/A1, A1F/A2, A1F/A3
- A1F/SA, A2F/SA, A3F/SA

Other possible conductor types not included above are not specifically excluded.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050(466):1990, *International Electrotechnical Vocabulary – Chapter 466: Overhead lines*

IEC 60104:1987, *Aluminium-magnesium-silicon alloy wire for overhead line conductors*

IEC 60888:1987, *Zinc-coated steel wires for stranded conductors*

IEC 60889:1987, *Hard-drawn aluminium wire for overhead line conductors*

IEC 61089:1991, *Round wire concentric lay overhead electrical stranded conductors*

IEC 61232:1993, *Aluminium-clad steel wires for electrical purposes*

IEC 61395:1998, *Overhead electrical conductors – Creep test procedures for stranded conductors*

3 Definitions

For the purpose of this International Standard the following definitions apply:

3.1
aluminium
all types of aluminium and aluminium alloys listed

3.2
conductor
material intended to be used for carrying electric current consisting of a plurality of uninsulated wires twisted together

[IEV 466-01-15 modified]

3.3
concentric lay stranded conductor
conductor composed of a central core surrounded by one or more adjacent layers of wires being laid helically in opposite directions

3.4
direction of lay

3.4.1
direction of lay (general definition)
direction of twist of a layer of wires as it moves away from the viewer

NOTE A right-hand lay is a clockwise direction and a left-hand lay is an anti-clockwise direction.

[IEV 466-10-07 modified]

3.4.2
direction of lay (alternative definition)
the direction of lay is defined as right-hand or left-hand

NOTE With right-hand lay, the wires conform to the direction of the central part of the letter Z when the conductor is held vertically. With left-hand lay, the wires conform to the direction of the central part of the letter S when the conductor is held vertically.

3.5
equivalent wire diameter
the diameter of a round wire which would have the same cross-sectional area, mass and electrical resistance as a given formed wire of the same material

3.6
compactness ratio
area 1/area 2 – where area 1 is the total cross-sectional area of the conductor including the core and area 2 is the area of a circle with diameter equal to the conductor outside diameter

3.7
fill ratio
area 1/(area 2 − area 3) – where area 1 is the cross-sectional area of the aluminium portion of the conductor, area 2 is the area of a circle of diameter equal to the conductor outside diameter and area 3 is the area of a circle circumscribing the core of a composite conductor (0 for a homogeneous conductor)

3.8
formed wire
filament of metal having a constant cross-section and a non-circular shape

3.9
lay length
axial length of one complete turn of the helix formed by an individual wire in a stranded conductor

3.10
lay ratio
ratio of the lay length to the external diameter of the corresponding layer of wires in the stranded conductor

[IEV 466-10-06 modified]

3.11
lot
group of conductors manufactured by the same manufacturer under similar conditions of production

NOTE A lot may consist of part or all of the purchased quantity.

3.12
nominal
name or identifying value of a measurable property by which a conductor or component of a conductor is identified and to which tolerances are applied

NOTE Nominal values should be target values.

3.13
round wire
filament of drawn metal having a constant circular cross-section

3.14
steel ratio
the ratio of steel area to aluminium area as a percentage in AxF/Syz conductors

4 Designation system

A designation system is used to identify stranded conductors made of formed aluminium, with or without steel wires.

Homogeneous aluminium conductors are designated AxF, where x identifies the type of aluminium.

Composite aluminium conductors are designated AxF/Ay or AxF/AyF, where AxF identifies external wires (or the envelope) and Ay or AyF identifies internal wires (or the core).

Composite aluminium-steel conductors are designated AxF/Syz or AxF/SA, where AxF identifies the external aluminium wires (envelope), and Syz or SA identifies the steel core. In the designation of zinc coated steel wires, y represents the type of steel (regular, high or extra high strength) and z represents the class of zinc coating (A or B).

Conductors are identified as follows:

a) a code number giving the equivalent conductive section of A1F aluminium expressed in mm^2;
b) a code number giving the area of the core material in mm^2, if used;

c) a designation identifying the type of wires constituting the conductor. For composite conductors the first designation applies to the envelope and the second to the core;

d) a number giving the nominal diameter of the conductor.

EXAMPLE 1 500-A1F-262: conductor made of A1F formed aluminium wires. Its area is 500 mm^2 and it is ($262 \times 0{,}1$) mm in diameter.

EXAMPLE 2 505/65-A1F/S1A-281: conductor made of A1F formed aluminium wires and S1A regular strength steel with class 1 zinc coating. The area of A1F aluminium is 505 mm^2 and the area of S1A steel is 65 mm^2 . The conductor nominal diameter is ($281 \times 0{,}1$) mm.

The following are examples of some possible conductor types. Conductors made of different combinations of wire types are also permitted.

- A1F, A2F, A3F
- A1F/S1A, A1F/S1B, A1F/S2A, A1F/S2B, A1F/S3A
- A1F/A1, A1F/A2, A1F/A3
- A1F/SA, A2F/SA, A3F/SA

5 Requirements for stranded conductors

5.1 Material

Stranded conductors shall be made up of formed aluminium wires and, when applicable, of round zinc-coated or aluminium clad steel wires or round aluminium wires. Before stranding, all wires shall have the properties specified in IEC 60104, IEC 60888, IEC 60889 or IEC 61232 as applicable (see note). Wires formed before stranding shall have properties calculated based on their equivalent round wire diameters.

NOTE The resistivity of these metals is as follows (in increasing order):

– A1F: 28,264 n$\Omega\times$m (corresponding to 61 % IACS);

– A2F: 32,530 n$\Omega\times$m (corresponding to 53 % IACS);

– A3F: 32,840 n$\Omega\times$m (corresponding to 52,5 % IACS).

5.2 Formed wires

Three production processes are recognized in this standard. One uses wires which are shaped in one process and stranded in another. The second method both forms the wires and then strands the wires in a single operation. In the third method a layer of round wires is first stranded and then that layer is compacted to a circular cross-section. Additional layers of round wires may be stranded and compacted or additional layers of formed wires may be stranded over the compacted core.

In any of these cases the materials shall comply with IEC 60889 or IEC 60104.

In the first case, the tests shall be performed on the formed wires prior to stranding and the properties shall be based on the equivalent wire diameters. In the other cases, the tests shall be performed on the round wires prior to forming and stranding and properties shall be based on the round wire diameter prior to forming.

If tests on individual wires are required after stranding, the purchaser and manufacturer shall agree to the requirements prior to order placement.

Typical types of formed wire conductors can be found in figures 1a, 1b and 2.

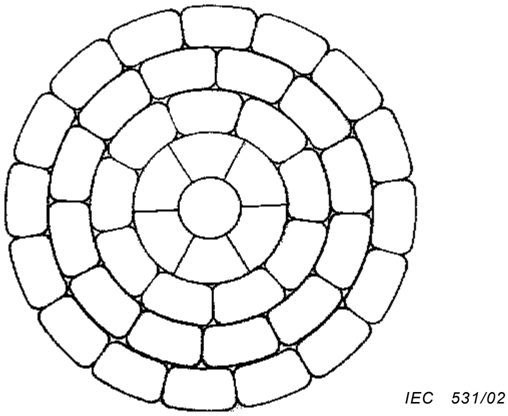

Figure 1a – Three-layer conductor made of formed wires type AxF/ Sxy

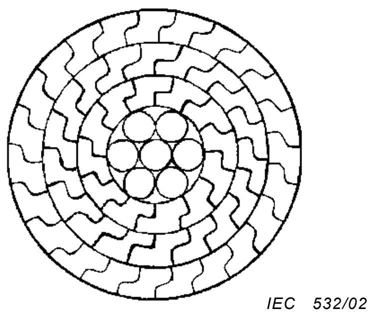

Figure 1b – Three-layer conductor made of formed wires type AxF/Sxy

Figure 1 – Formed wire conductors – Three-layer

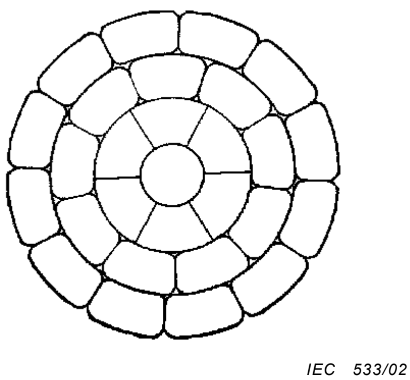

Figure 2 – Two-layer conductor made of formed wires type AxF/AyF

5.3 Conductor sizes

A list of some possible conductor sizes is given as guidance in annex D. It is recommended that for new designs of conductor sizes, these should be selected from those listed. Conductors with diameters and mechanical characteristics equal to existing or established designs of conductors are also provided in annex D to aid in the selection of conductors to be used to replace conductors on existing overhead lines.

Other sizes and stranding not included in this standard may be designed and supplied as agreed upon by the manufacturer and purchaser, and the relevant requirements of this standard shall apply.

5.4 Surface

The surface of the conductor shall be free from all imperfections visible to the naked eye (normal corrective lenses accepted), such as nicks, indentations, etc., not consistent with good commercial practice.

5.5 Stranding

5.5.1 All wires of the conductor shall be concentrically stranded. Adjacent wire layers shall be stranded with reverse lay directions. The direction of lay of the external layer shall be "right-hand" except when otherwise indicated in the purchase order.

5.5.2 The wires in each layer shall be evenly and closely stranded around the underlying wire or wires.

5.5.3 The lay ratios for the steel wire layers shall be as follows:

a) the lay ratio for the 6-wire layer of 7 and 19-wire steel cores shall be not less than 16 nor more than 26;
b) the lay ratio for the 12-wire layer of 19-wire steel core shall be not less than 14 nor more than 22;
c) for certain conductor constructions, as indicated in figure 1b, the minimum lay ratio may be less than 10 for both inner and outer layers.

5.5.4 The lay ratios for the aluminium layers of all types of conductor shall be as follows:

a) the lay ratio for the outside layer of aluminium wires shall be not less than 10 nor more than 14;
b) the lay ratios for the inner layers of aluminium wires shall be not less than 10 nor more than 16.

5.5.5 In a 19-wire steel core, the lay ratio of the 12-wire layer shall be not greater than the lay ratio of the 6-wire layer. Similarly, in a conductor having multiple layers of aluminium wires, the lay ratio of any aluminium layer shall be not greater than the lay ratio of the aluminium layer immediately beneath it.

5.5.6 All steel wires shall lie naturally in their position in the stranded core, and where the core is cut, the wire ends shall remain in position or be readily replaced by hand and then remain approximately in position. This requirement also applies to the outer layer of aluminium wires of a conductor.

5.5.7 Before stranding, aluminium and steel wires shall have approximately uniform temperatures.

5.6 Joints

5.6.1 There shall be no joints of any kind made in the steel core wire or wires during stranding.

5.6.2 No more than one joint per aluminium finished wire as permitted in the references of IEC 61089 shall be used per length of conductor.

5.6.3 During stranding, no aluminium wire welds shall be made for the purpose of achieving the required conductor length.

5.6.4 Joints are permitted in aluminium wires unavoidably broken during stranding, provided such breaks are not associated with either inherently defective wire or with the use of short lengths of aluminium wires. Joints shall conform to the geometry of original wire, i.e. joints shall be dressed smoothly with a shape equal to that of the parent wires and shall not be kinked.

5.6.5 Joints in aluminium wires shall not exceed those specified in table 1. These joints shall not be closer than 15 m from a joint in the same wire or in any other aluminium wire of the completed conductor.

5.6.6 Joints shall be made by electric butt welding, electric butt cold upset welding or cold pressure welding (see note 1) and other approved methods. These joints shall be made in accordance with good commercial practice. The first type of joints shall be electrically annealed for approximately 250 mm on both sides of the weld.

Table 1 – Number of joints permitted in aluminium conductors

Number of aluminium layers	Joints permitted per conductor length
1	2
2	3
3	4
4	5

While the joints specified in 5.6.4 are not required to meet the requirements of unjointed wires (see note 2), they shall withstand a stress of not less than 75 MPa for annealed electric butt welded joints, and not less than 130 MPa for cold pressure and electric butt cold upset welded joints. The manufacturer shall demonstrate that the proposed welding method is capable of meeting the specified strength requirements.

NOTE 1 It is practice in some countries to require the annealing of cold pressure joints made in A2 or A3 material.

NOTE 2 The behaviour of properly spaced wire joints in stranded conductor is related to both tensile strength and elongation. Because of higher elongation properties, the lower strength annealed electric butt welded joint gives a similar overall performance to that of a cold pressure or an electric butt cold upset welded joint.

5.7 Linear density – Mass per unit length

The masses given in the tables of annex D have been calculated for each size and stranding of conductor using densities for the aluminium and zinc-coated steel wires as given in the standards listed in 5.1, the stranding increments given in table 2, and the cross-sectional areas for aluminium and zinc-coated steel wires based on their theoretical unrounded diameters.

The increments (see note 1) in per cent, for mass due to stranding, based on the mean lay ratios given in 5.5.4 and 5.5.5, shall be those shown in table 2 or, if more precision is required, actual lay factors may be used to calculate actual increments.

Whenever a conductor has to be greased (see note 2), the nominal mass of grease shall be calculated according to the method given in annex C.

NOTE 1 The mass of a stranded conductor is affected by the lay factor. With the exception of the centre wire, all wires are longer than the stranded conductor and the increase in mass depends upon the lay ratio employed.

NOTE 2 Grease requirements are under consideration.

Table 2 – Standard[a] increments due to stranding

Stranding			Increment[a] (increase) %	
Number of aluminium layers[b]	Number of steel wires	Number of layers	Aluminium[c]	Steel
1	0	–	1,5	–
	1	–	1,5	–
2	0	–	2,0	–
	1	–	2,0	–
	7	1	2,0	0,43
3	0	–	2,0	–
	7	1	2,5	0,43
	19	2	2,5	0,77
4	0	–	3,0	–
	19	2	3,0	0,77

[a] These increments have been calculated using average lay ratios for each applicable layer of aluminium or steel.

[b] Number of layers of each type of wire not including the central wire.

[c] Numbers of wires per layer are not specified, thus these increments are typical rounded values.

5.8 Conductor strength

5.8.1 The rated tensile strength of a homogeneous aluminium conductor shall be taken as the sum of the minimum tensile strength of all wires as defined in 5.8.4.

5.8.2 The rated tensile strength of composite AxF/Syz or AxF/SA conductors shall be the sum of the tensile strength of the aluminium portion plus the strength of steel corresponding to an elongation compatible with that of aluminium at rupture load. For the purpose of specification and practicability, this strength of steel is conservatively established as the stress corresponding at 1 % elongation in a 250 mm gauge length.

5.8.3 The rated tensile strength of composite aluminium conductors (A1F/A2 or A1F/A3) shall be taken as the sum of the tensile strength of A1F portion plus 95 % of the tensile strength of the A2 or A3 portion.

5.8.4 The tensile strength of any single wire is the product of its nominal area and the appropriate minimum stress given in the standards listed in 5.1.

6 Tests

6.1 Classification of tests

6.1.1 Type tests

Type tests are intended to verify the main characteristics of a conductor which depend mainly on its design. They shall be carried out once – be it for a new design, a new manufacturer or manufacturing process of conductor and then subsequently repeated only when the design, manufacturer or manufacturing process is changed.

Type tests shall be carried out only on a conductor which meets the requirements of all the relevant sample tests.

Type test data shall be provided for established designs.

6.1.2 Sample tests

Sample tests are intended to guarantee the quality of conductors and compliance with the requirements of this standard.

6.2 Test requirements for new conductor designs

Test requirements are as follows:

6.2.1 Type tests

a) Joints in aluminium wires
b) Stress-strain
c) Breaking strength of conductor
d) Creep

6.2.2 Sample tests

a) On wire before stranding: as per 5.1 and 5.2.
b) On the conductor:
   – cross-sectional area;
   – overall diameter;
   – linear density;
   – surface condition;
   – lay ratio and direction of lay;
   – wrap test on aluminium wires removed from a conductor where wire forming and stranding are done in a single operation.

6.3 Sample size

Samples for the test specified in 6.2.2 shall be taken at random from the outer end of 10 % of the drums of conductor. However, the inspection of the surface condition of the conductor shall be carried out on every drum.

6.4 Sample length

6.4.1 Samples for tests on individual aluminium wires and, when applicable, zinc-coated or aluminium clad steel core wires shall be taken before stranding and tested in accordance with the standard listed in 5.1.

6.4.2 Samples for tests of individual wires after stranding when requested shall consist of a 1,5 m length cut from the outer end of the coils or drums of conductors.

6.4.3 The sample length required for tensile and stress-strain tests shall be at least 400 times the diameter of the conductor but not less than 10 m.

6.4.4 The length of samples in this subclause is the minimum required for a good accuracy of stress-strain curves. In cases where the manufacturer can demonstrate to the satisfaction of the purchaser with significant comparative test results that a shorter length can give equally accurate results, then a short length of samples may be used.

6.5 Type tests

6.5.1 Joints in aluminium wires

The manufacturer shall demonstrate to the purchaser that the method used for jointing aluminium wires meets the strength requirements of 5.6 by supplying recent test results or by performing the necessary tests.

6.5.2 Stress-strain curves

Stress-strain curves shall be supplied as a type test when requested by the purchaser and shall represent the best knowledge of the behaviour of the purchased conductor under load.

If agreed between purchaser and supplier when placing an order, stress-strain tests shall be performed on the conductor and, when applicable, on the steel core, in accordance with the method given in annex B.

6.5.3 Tensile test of the conductors

When tests for breaking strength of conductors are required, these shall withstand, without the fracture of any wire, not less than 95 % of their rated tensile strength calculated according to 5.8.

The breaking strength of conductors shall be determined by pulling a conductor in a suitable tensile testing machine having an accuracy of at least ±1 %. It is recommended that the rate of increase of load should be as described in B.6. For the purposes of this test, appropriate fittings shall be installed on the ends of the conductor samples. During this test, the breaking strength of the conductor shall be determined by the load attained at which one or more wires of the conductor are fractured. A retest – or up to a total of three tests – may be made if wire fracture occurs within 1 cm of the end fittings and the tensile strength falls below the specified breaking strength requirements.

6.5.4 Creep test

Creep test, when required, shall be conducted in accordance with IEC 61395.

6.6 Sample tests

6.6.1 Cross-sectional area

6.6.1.1 The cross-sectional area of the aluminium portion of a stranded conductor shall be taken as the sum of the areas of the aluminium wires composing the conductor based on the diameter values obtained in accordance with 6.6.1.4 or 6.6.1.5.

6.6.1.2 This area shall not vary from the nominal value by more than ±2 % in any sample and by more than ±1,5 % for the average of any four measured values at locations selected at random with a minimum spacing of 20 cm.

6.6.1.3 The area of steel core, where applicable, shall be taken as the sum of the areas of the solid wires composing the steel core based on the diameter measurements made in accordance with 6.6.1.4.

6.6.1.4 The diameter of a round wire shall include the metallic coating, where applicable, and shall be measured using a micrometer calliper having flat surfaces on both the anvil and the end of the spindle and graduated to be read in millimetres to two decimal places. The diameter in millimetres shall be the average of three diameter measurements, each of which is the average of the maximum and minimum readings at a point taken near each end and in the centre of the sample.

6.6.1.5 The equivalent wire diameter of a formed wire shall be calculated by using the weight, length and density as described in IEC 60889.

6.6.2 Conductor diameter

The conductor diameter shall be measured midway between the closing die and the capstan on the stranding machine.

Measurements shall be made with a calliper graduated to be read in one-hundredths of a millimetre (0,01 mm). The diameter shall be the average of two readings, rounded to two decimal places of a millimetre, taken at right angles to each other at the same location.

The diameter of the conductor shall not vary by ±1 % for diameters larger than or equal to 10 mm and by ±0,1 mm for diameters smaller than 10 mm.

6.6.3 Linear density – Mass per unit length

The linear density (mass per unit length) of the conductor shall be determined by using apparatus capable of achieving an accuracy of ±0,1%.

The tolerance on the mass of the conductor per unit length without grease shall not exceed ±2 %.

The mass of grease in a conductor shall be determined from the difference between the mass of the conductor with grease and its mass after removing all the grease. The mass of grease shall correspond at least to the minimum values specified in annex C.

6.6.4 Breaking strength of wires

When required, breaking strength tests shall be made on wires obtained from conductors after stranding. The specimen of wires shall be taken from the conductor sample and shall be removed from its position, and straightened, care being taken not to stretch it in so doing.

The cross-sectional area of the wire is determined from the diameter measurements indicated in 6.6.1.3 and 6.6.1.4 in the case of formed wire. Then, the straightened wire shall be installed in a suitable tensile testing machine. The load shall be applied gradually with a rate of separation of the jaws not less than 25 mm/min and not greater than 100 mm/min.

The load at failure for wires formed prior to stranding divided by the cross-sectional area of the wire shall be not less than 95 % of the applicable stress requirements prior to stranding. (The 5 % reduction accounts for handling and twisting of wires during stranding.) For wires formed after stranding, see 5.2.

6.6.5 Surface condition

The surface of the conductor shall comply with the requirements of 5.4.

6.6.6 Lay ratio and direction of lay

The lay ratio of each layer of the conductor shall be obtained through the ratio of the measured lay length to the external diameter of the applicable layer.

The obtained values shall comply with the requirements of 5.5. In addition, the direction of each layer shall be noted and shall also comply with the requirements of 5.5.

6.7 Inspection

The manufacturer shall inform the purchaser at the time of purchase of the location and date of type and sample testing. The manufacturer shall afford the inspector representing the purchaser all necessary and sufficient testing facilities in order to satisfy him that the material is being furnished in accordance with this standard.

When inspection has to be made by the purchaser before shipment, the tests shall all be made within 10 days after receipt of a notice by the purchaser that the material is ready to test, and the material shall be accepted or rejected at the manufacturer's plant. If the purchaser does not have a representative present at the manufacturer's plant to test the material at the expiration of the said 10 days, the manufacturer shall make the necessary tests and, when requested, provide the purchaser with official copies of the results of such tests. The purchaser shall accept or reject the material in accordance with the results of such tests. Alternatively, the manufacturer may provide relevant test results if these have already been carried out in production.

6.8 Acceptance or rejection

Failure of a test specimen to comply with any one of the requirements of this standard shall constitute grounds for rejection of the lot represented by the specimen.

If any lot is so rejected, the manufacturer shall have the right to test, only once, all individual drums of conductors in the lot and submit those which meet the requirements for acceptance.

7 Packaging and marking

7.1 Packaging

The conductor shall be suitably protected against damage which could occur in ordinary handling and shipping.

The following shall be agreed upon between the manufacturer and the purchaser at the time of placing the order or at the earliest possible time:

a) the type and size of package and method of packing;
b) the packaging size and drum bore requirements and also the availability of the inner end of the conductor for grounding purposes, where conductor stringing practices require special consideration.

7.2 Marking and tare

The gross, net and tare weight, length (or length and number of pieces if it is agreed to supply more than one length on the same drum), designation, and any other necessary identification, shall be suitably marked inside the package. This same information, together with the purchase order number, the manufacturer's serial number (if any) and all shipping marks and other information shall appear on the outside of each package.

7.3 Random lengths

Random lengths of conductors unavoidably obtained during production shall not exceed 5 % of the total order, providing that no piece is less than 50 % of the agreed length of conductor per drum.

Annex A
(normative)

Information to be supplied by purchaser

The following information shall be provided by the purchaser:

a) quantity of conductors;
b) cross-sectional area, designation and stranding of conductor;
c) length of conductor per drum, its tolerance and, where applicable, matching of conductor lengths;
d) type and size of package and method of packing;
e) special packaging requirements, if any;
f) lagging requirements, if any;
g) if inspection is required and the place of inspection;
h) whether tests on wires after stranding are required;
i) whether tests on welded joints made in wires prior to stranding are required;
j) whether conductor breaking strength tests are required;
k) whether conductor stress-strain tests are required;
l) direction of lay. If this information is omitted, the direction of the external lay shall be right-hand;
m) requirements for grease, if any (type, properties, etc.);
n) whether creep tests are required.

Annex B
(normative)

Stress-strain test method

B.1 Sample length

A conductor length as given in 6.4.3 shall be tested to obtain representative stress-strain curves.

B.2 Test temperature

The temperature of the sample shall be recorded and shall not vary by more than ±2 °C during the test. Temperature readings shall be taken at the beginning and end of each hold period.

B.3 Sample preparation

Great care shall be taken in the preparation of test samples. Relative displacements as small as 1 mm between the steel core and the aluminium layers of the conductor cause significant changes in the measured stress-strain curves. The sample preparation shall be as follows:

Before removing the sample from the drum, fit a bolted clamp 5 m ± 1 m from the end of the conductor length. The clamp shall supply sufficient pressure to prevent relative wire movements in the conductor.

Unwind the desired length of conductor from the drum and install another bolted clamp at the required distance from the first clamp. Apply adhesive tape and cut the conductor at a distance from the clamp just far enough to allow room for applying dead-end fittings.

During transportation to the test laboratory, the sample shall be properly protected from damage. The diameter of the coil or drum of the sample shall be at least 50 times the conductor diameter.

End fittings such as compression, epoxy type or solder type approved by the purchaser shall be used for stress-strain tests.

Care shall be taken not to damage any wire during the end preparation of the sample.

The application of the end fitting shall not introduce any slack in the wires which might alter the stress-strain curves of the conductor.

B.4 Requirements (only for compression fittings)

Whenever compression fittings are used for testing AxF/Syz conductors, the following methodology shall be used.

Slide the aluminium sleeve on to the conductor. Cut back the aluminium wires to allow room for the steel terminal, the extrusion of the steel terminal and the extrusion of aluminium wires by the aluminium compression sleeve. The space required between the aluminium wires and the steel terminal, before crimping, is typically 30 mm to 40 mm. Slide the compression steel dead-end terminal on to the steel core. Crimp the steel terminal with a 2 % to 10 % maximum overlap, starting from the other core end.

Pull the aluminium sleeve on to the steel terminal. Leave 40 mm of space if the conductor diameter is less than or equal to 30 mm, and 50 mm of space if the conductor diameter is greater than 30 mm, between the end of the aluminium sleeve and the shoulder of the steel terminal for extrusion. Make the first crimp on the tapered mouth of the aluminium sleeve. This locks the sleeve in place and inhibits extrusion of aluminium towards the test span. Proceed to crimp in the direction away from the span in small bites of 20 % on uncompressed metal. Stop crimping before the filler hole in the sleeve is reached; the steel terminal and core are too small to support the crimped aluminium sleeve in this region. Continue crimping towards the eye, on the other side of the terminal pad to lock the sleeve on to the expanded portion of the steel terminal.

The aluminium sleeve shall be oriented so that there is no interference with conductor movement during the test.

B.5 Test set-up

The test sample shall be supported in a trough over its full length and the trough adjusted so that the conductor will not lift by more than 10 mm when under tension. This shall be ascertained by measurement rather than by tensioning the conductor.

This distance between the clamp indicating the gauge length and the mouth of the terminal sleeve shall be monitored with a calliper during the test to ensure that, after the 85 % load cycle, when unloaded to the preload, it does not change by more than 1 mm from the value before the test. (During the test the distance may change by more than 1 mm.) A resolution of 0,1 mm is adequate.

The conductor strain shall be evaluated from the measured displacements at the two ends of the gauge length of the conductor. The gauge reference targets shall be attached to the bolted clamps which lock the conductor wires together. Target plates may be used with dial gauges or displacement transducers and care shall be taken to position the plates perpendicular to the conductor. Twisting the conductor, lifting it and moving it from side to side by the maximum amounts expected during the test should introduce no more than 0,3 mm error in the reading.

NOTE 1 Slack may cause the stranded wires to bulge radially outwards by several millimetres. The bulge disappears at higher tensions as a result of elastic strain and reappears when the tension is released.

NOTE 2 Pinging noises at higher tensions may be an indication that layers of wire are slipping or the aluminium is slipping on the steel core because the bolted clamps are not tight enough. The result of loose bolted clamps is that, as the slack moves towards the span, the targets are carried with them and the measured strain will be less than the true strain.

B.6 Test loads for conductors

The loading conditions for stress-strain tests for conductors shall be as follows.

a) Load initially to 2 % of RTS (rated tensile strength) to straighten the conductor. After straightening, remove the load (see note 1) and set the strain gauges to zero at zero tension.

b) For non-continuous stress-strain data recordings, take the strain readings at intervals of 2,5 % RTS rounded off to the nearest kilonewton (kN).

c) Load to 30 % RTS and hold for 30 min. Take readings after 5 min, 10 min, 15 min and 30 min during the hold period. Release to the initial load.

d) Re-load to 50 % RTS and hold for 1 h. Take readings after 5 min, 10 min, 15 min, 30 min, 45 min and 60 min. Release to the initial load.

e) Re-load to 70 % RTS and hold for 1 h. Take readings after 5 min, 10 min, 15 min, 30 min, 45 min and 60 min. Release to the initial load.

f) Re-load to 85 % RTS and hold for 1 h. Take readings after 5 min, 10 min, 15 min, 30 min, 45 min and 60 min. Release to the initial load.

g) After the fourth application of load, again apply tension, increasing uniformly, until the actual breaking strength is reached. Simultaneous readings of tension and elongation shall be taken up to 85 % RTS (see note 2) at the same intervals as for previous loading.

h) The rate of increase of load shall be uniform during testing. The time required to reach 30 % RTS shall not be less than 1 min nor more than 2 min. The same rate of loading shall thereafter be maintained throughout the tests.

NOTE 1 When wedge type dead-end clamps are used for testing, removing the load may loosen the grip of the wedge; consequently in this case, the initial load of 2 % RTS should be kept while setting strain gauges to zero.

NOTE 2 Extra caution should be exercised when testing conductors, especially A1F designation, above 70 % RTS.

B.7 Test loads for steel core only

The loading conditions for stress-strain tests for the steel core of AxF/Syz conductors shall be as follows:

The test shall consist of successive applications of load applied in a manner similar to that for the conductor at 30 %, 50 %, 70 % and 85 % RTS.

The steel core shall be loaded until the elongation at the beginning of each hold period corresponds to that obtained on the conductor at 30 %, 50 %, 70 % and 85 % RTS, respectively.

B.8 Stress-strain curves

Obtain the stress-strain curve by drawing a smooth line through the 30 min and 1 h points at 30 %, 50 %, 70 % and 85 % RTS loading. To obtain the typical curve, remove from the lower end the presence of any aluminium slack that can be related to any observed extrusion entering the span from the compression dead-ends. Adjust the typical curve to pass through zero. Both the laboratory and the typical stress-strain curves shall be submitted to the purchaser.

Annex C
(normative)

Nominal mass of grease for stranded conductors using formed wires

When AxF/Sxy bare conductors need to be greased in order to reduce the risk of corrosion in some environments, the mass of grease can be calculated using the method given in this annex. Since conductors which employ formed wires have very little interstitial space between the shaped strands it is only necessary to consider the voids in the round wire core when calculating grease mass.

Assuming the grease will completely fill the voids between the core wires, the volume of grease in any given layer of conductor can be calculated from the following equation (see table C.1):

$$V_g = (D_e^2 - D_i^2)\ \pi/4 - n\pi d^2/4 \qquad \text{(C.1)}$$

where

D_e is the external diameter of the layer;

D_i is the internal diameter of the layer;

d is the diameter or equivalent diameter of the wire in the layer;

n is the number of wires in the layer;

V_g is the volume of grease in the layer.

For conductors having multiple core layers, the total mass of grease can be obtained by adding the values obtained for each layer.

Since there is a geometric relationship between all parameters of equation (C.1), it is possible to express the total mass of grease in a conductor by the following equation:

$$M_g = k \times d_a^2 \qquad \text{(C.2)}$$

where

k is the factor which depends on the conductor stranding and the grease density and the fill factor (percentage of theoretical volume);

d_a is the core wire diameter in millimetres;

M_g is the mass of the grease in kg/km.

Values of k are given in table C.1 for a grease density of 0,87 g/cm^3 and a fill factor of 0,7.

Table C.1 – Coefficients *k* for mass of grease

Stranding (steel core greased)		*k*
Aluminium	Steel	
All	–	–
	1	–
	7	0,30
	19	0,46

Annex D
(informative)

Recommended conductor sizes and tables of conductor properties

D.1 General remarks

A list of possible conductor sizes as well as examples of typical cross-sectional drawings of some of the possible design configurations is given as guidance in this annex. It is recommended that, for new designs of conductor, sizes should be selected from those listed. Conductors with diameters and mechanical characteristics equal to existing or established designs of conductors are also provided to aid in the selection of conductors to be used to replace conductors on existing overhead lines. Other sizes and stranding not included in this standard may be designed and supplied as agreed upon by the manufacturer and purchaser, and the relevant requirements of this standard shall apply.

The code number which precedes the conductor designation (example: 500 in 500-A2F-28) represents the equivalent conductive area of A1 aluminium.

Conductors with the same code number have the same d.c. resistance, independent of their type, designation or stranding. Thus, the proposed conductor sizes allow an easier selection of the best conductor type when the conductivity (or the current-carrying capacity) is specified from system studies.

Care should be taken if replacing existing overhead lines; the current-carrying capacity may be the same, but the area of heat emission reduced.

D.2 Calculation of conductor properties

Conductors are specified with a code number followed by a material designation and then by an outside diameter designator.

EXAMPLE 1 500-A1F-262

EXAMPLE 2 505/65-A1F/S1B-281

Starting from this input, all the conductor properties can be calculated and each value obtained is rounded to the number of significant figures compatible with the requirements of this standard.

D.2.1 Total area of aluminium wires, A_a

A_a = code number × resistivity of AxF/ resistivity of A1 (mm^2)

This area is rounded to three significant figures for conductors smaller than 1 000 mm^2 and four figures for conductors larger than 1 000 mm^2.

D.2.2 Equivalent round aluminium wire diameter, d_a

$d_a = [(4/\pi)(A_a/\text{number of aluminium wires})]^{0,5}$ (mm)

D.2.3 Core wire diameter, d_s

In layers of round wires with uniform diameter, the number of wires increases by six from one layer to the following layer. Therefore, when all layers of a core have identical diameters, the total number of wires is one of the following: 1, 7, 19, etc.

$d_s = [(4/\pi)(A_c/\text{number of core wires})]^{0,5}$ (mm)

Given the core area (A_c), the minimum and maximum wire sizes in IEC 60104 and IEC 60889 will determine the number of wires in the core.

D.2.4 Conductor diameter, D

The overall conductor diameter is given as the last number in the conductor designation.

D.2.5 Linear mass, M_c

The cross-sectional areas of steel and aluminium wires are multiplied by the applicable densities at 20 °C of 2,70 kg/dm^3 for AxF or Ax wires and 7,78 kg/dm^3 for Syz wires as applicable.

The result is increased by the increments given in table 2 of this standard in order to take into account the fact that wires are formed in a helix.

The resulting mass M_c is then rounded to one decimal place.

D.2.6 Rated tensile strength, RTS

The RTS is calculated according to 5.8 and rounded to two decimal places.

D.2.7 DC resistance

The d.c. resistance of a conductor is based on the resistance of the aluminium portion(s) multiplied by the increments of table 2. This value is expressed to four decimal places.

Table D.1 – Characteristics of some examples of some A1F conductors

Code number	Cross- section mm²	Diameter mm	Linear mass kg/m	Rated strength kN	DC resistance at 20 °C Ω/km
100	100	12,16	0,275	17,5	0,2873
125	125	13,42	0,344	21,3	0,2299
160	160	15,01	0,439	27,2	0,1796
200	200	16,65	0,550	33	0,1437
250	250	18,49	0,688	41,3	0,1149
315	315	20,65	0,866	52	0,0912
400	400	23,57	1,105	66	0,0722
450	450	24,91	1,244	74,3	0,0642
500	500	26,20	1,383	82,5	0,0578
560	560	27,62	1,548	92,4	0,0516
630	630	29,23	1,742	100,8	0,0459
710	710	31,11	1,964	115,5	0,0407
800	800	32,97	2,212	128	0,0361
900	900	35,06	2,495	148,5	0,0322
1 000	1 000	36,87	2,772	160	0,0290
NOTE Stranding increment differences may give slightly different values from IEC 61089 [1].					

[1] IEC 61089:1991, *Round wire concentric lay overhead electrical stranded conductors.*

Table D.2 – Characteristics examples of some A1F/S1A conductors

Code number	Cross-section	Steel wires		Conduc-tor diameter	Linear mass			Rated tensile strength	DC resistance at 20 °C
		Num-ber	Diameter		Aluminium	Steel	Total		
	mm²		mm	mm	kg/km	kg/km	kg/km	kN	Ω/km
100/17	100	1	4,61	12,0	274	130	404	34,8	0,2855
125/7,5	125	1	3,09	13,5	342	59	401	28,9	0,2284
160/10	160	1	3,49	15,3	441	75	516	37	0,1798
208/28	208	7	2,25	18,3	576	217	793	66,9	0,1383
250/32	250	7	2,43	19,9	690	255	945	78,3	0,1153
300/39	300,5	7	2,67	21,8	831	307	1 139	94,4	0,0961
370/48	370,9	7	2,96	24,1	1 026	377	1 403	114	0,0777
400/52	400	7	3,07	25,1	1 104	407	1 511	121	0,0721
456/59	456	7	3,28	26,7	1 259	463	1 722	138	0,0632
505/65	505,3	7	3,45	28,1	1 395	513	1 908	153	0,0571
593/77	593,5	7	3,74	31,2	1 646	602	2 248	185	0,0488
622/153	622,5	19	3,20	34,0	1 834	1 198	3 032	276	0,0437
710/114	710	19	2,76	34,1	1 976	894	2 870	246	0,0410
731/77	731,5	19	2,27	34,0	2 032	603	2 635	210	0,0367
800/128	800	19	2,93	36,2	2 226	1 007	3 233	275	0,0363
902/74	901,9	19	2,22	36,1	2 518	579	3 097	235	0,0323
975/167	974,9	19	3,34	40,6	2 728	1 308	4 036	345	0,0300
1 000/130	1 000	19	2,95	39,8	2 779	1023	3 802	308	0,0290
1 092/89	1 092,5	19	2,44	40,6	3 046	701	3 747	280	0,0267

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